Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

SOME INFLUENCES WHICH AFFECT THE RAPIDITY OF VOLUNTARY MOVEMENTS.[1]

By F. B. DRESSLAR, Fellow in Psychology in Clark University.

The purpose of this research was (1) to find a convenient and accurate method of recording and timing rapid voluntary movements, and (2) to determine some of the conditions which influence the rate of such movements. The experiments were limited to a study of the rate at which one can tap on a Morse key. Three hundred taps were made as rapidly as possible at each test, and the condition of the subject noted. During the course of the experiments over 400 tests were made, involving more than 120,000 taps.

Apparatus. The apparatus used consisted of a kymograph with the revolving drum set perpendicularly, and covered with smoked paper. On a standard was fastened an electro-magnet which was put in a circuit alternately made and broken by a clock. Attached to the armature of this magnet was a projecting metal point which registered the seconds on the revolving drum. On the same standard was fastened a common clock movement, the escapement of which was alternately raised by an electro-magnet at one end, and by a resisting spring at the other, according as the electric circuit was made or broken by a Morse key. Thus with each tap on the key the escapement wheel was permitted to move one notch. To prevent jars this key was placed on an adjacent table, but near enough for the operator to manage the kymograph. Upon this key the taps recorded were made. In order to register the taps on the slowly moving drum, a silk cord was passed once around a small pulley substituted for the second hand of the clock. One end of this cord was made fast to a wire bearing a fixed writing point, the other to a counter-weight. The wire was held in a perpendicular position by passing it through two brass strips extending out from the

[1] The work was done under the direction of Dr. Warren P. Lombard, Assistant Professor of Physiology, to whom I am indebted for many suggestions in determining methods for work, and for help in devising apparatus.

board on which the clock was fastened. The writing point was fixed on the wire between these strips and the amplitude of its movement made correspond exactly to 300 taps on the key, by adjusting a wooden clasp on the upper strip. When the drum was moving, the line traced by the writing point formed an angle with the abscissa which varied according to the rapidity of the taps on the key.

To determine the time required to make 300 taps, perpendiculars were drawn to the seconds line from the points where the writing point began to rise and where it reached the upper limit of its motion. The seconds comprehended between these perpendiculars gave the time.

The following is an example of a normal record.

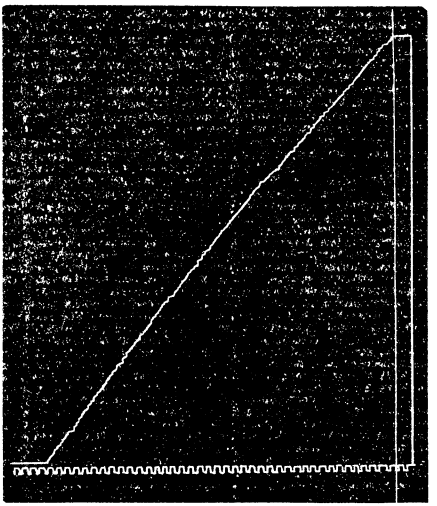


FIG. 1.

Method of Work. From 8 a. m. to 6 p. m. six tests of 300 taps each were made; one every two hours. The usual working hours of the day were thus covered by the experiments, and sufficient time intervened between the records for the subject to recover from any possible fatigue. Three hundred taps were chosen because it was thought that after practice this number would not be fatiguing[1] and at the

[1] It was noticed after the tests had all been made that many of the curves showed a decreasing rate towards the end of the 300 taps and thus gave evidence of incipient fatigue, though all sensations of fatigue had ceased with the first few days of the work. By actual count out of one hundred curves taken at random from the last month of work, seventy showed the effect of this unconscious fatigue. This strengthens the belief that the method used may prove useful as a mild but sensitive clinical test.

same time sufficiently great to show any fluctuation in the normal rate. The course of the experiments furnished no evidence that this number was not well chosen.

The fore-arm rested on a firm support and the tapping movements were as far as possible confined to the wrist. Throughout these experiments the subject gave his whole attention to the work, and made the 300 taps with the greatest possible rapidity. The condition of the operator was carefully recorded beneath each record, and especial attention given to any circumstance which it was thought might influence the rapidity of the taps.

Normal rate of voluntary taps. Table I, column 1, shows that the average rate attained for 300 taps for the time there recorded was 8.5 taps per second. Column 2 should not be included in the average, because during this period many conditions were introduced that more or less affected the normal rate. The most rapid rate attained for 300 taps for any single record was 10 taps per second. Even this last rate could be excelled for a short time. From 30 tests made at the beginning and near the end of the work, the rate for the left hand was found to be 5.3 taps per second.

TABLE I.

	1. No. of seconds required to make 800 taps.							2. No. of seconds required to make 800 taps.						
DATE.	8 A M	10 A M	12 M	2 P M	4 P M	6 P M	DATE.	8 A M	10 A M	12 M	2 P M	4 P M	6 P M
Feb. 3	37	38	36	35	34.5	36	Mar. 10	44.25	37	38	39	34	36
" 4	37	38	33.5	35.5	32.5	36	" 11	37	34.5	38	42	32.5	36
" 5	40	35.5	34.5	35.25	34.5	34.5	" 12	43	41	36	40.25	36	40
" 8	39.5	34	33.25	36	33.5	34.5	" 14	42	43	38.5	43	40	43.25
" 9	37	32.5	34	36.5	37		" 15	44	39	39	42	39	46
" 10	39.75	37	34.75	35	34	33	" 16	45	38	38.5	41	34	43
" 11	38	36.5	36.5	34.5	36	37	" 17	42	39.5	40	41.75	39	40
" 12	40.5	37.5	37	38	33	36	" 18	43.5	40	44	40	37	38
" 13	37	38.5	37.5	39.5	34.5	37	" 19	39	37.5	36.5	40	36	38
" 15	38.75	31.25	31.5	30	30.5	32	" 21	40.25	40	39	40	36	42
" 16	33.5		33.5	33.5	31.25	38.25	" 22	41	41	37.5	40	36.25	38
" 17	36.5	33	32	32.75	32	34	" 23	45	38	39	37.25	37	39
" 18	36	35.25	36.5	37.5	33	33	" 24	40	43.75	41	40.5	38	48
" 19	39	34.5	33.5	37.25	32	35	" 25	55	47.5	37.25	41.25	36.5	37
" 20	37	35	35	36.5	34.5	33	" 26	40.5	40.5	40	40	38.5	39
" 22	40.75	36	38.5	33			" 28	42.5	38.5	42.5	43	41	41.5
Aver.	37.8	35.4	34.6	35.5	33.5	35.1							

General average 35.3.

The rapidity with which the taps were made, at first suggested that the movements were not voluntary in the stricter sense, but more in the nature of tremor. To test this, the contacts of the Morse key produced by normal taps, were recorded on a revolving drum by a Deprèz signal, and each movement timed by a tuning fork of 100 V. D. These were compared with records taken in the same way for tremor of the wrist, and also of the fore-arm. All attempts to produce tremor of the wrist resulted in lateral movements instead of the up and down movements used in making the regular taps.

This fact, together with the greater rapidity of the tremor attained in both cases, seems to leave no doubt that the taps made were separate voluntary movements. Figure (2) shows the contrast (A, B) between the usual taps and tremor of the fore-arm, and (A', B') between the usual taps and tremor of the wrist. It will be seen from this figure that during short intervals the subject could make 10.5 taps per second, while the rate of the oscillations of the fore-arm during tremor was 12.2 per second, and for lateral tremor of the wrist 12.9 per second.

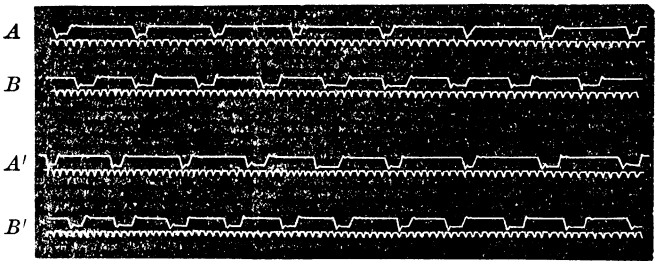


FIG. 2.

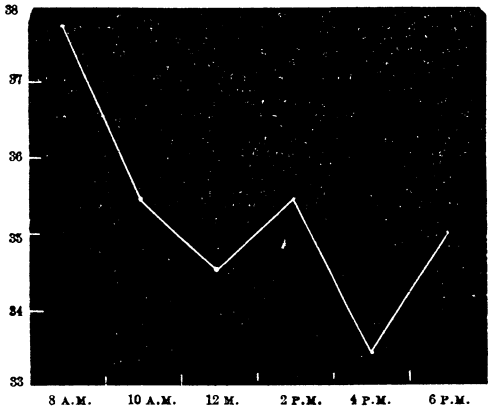
A and A' = Voluntary taps.
B and B' = Tremor; B of fore-arm, and B′ of wrist.

Voluntary Movements.			Tremor.		
Time in hundredths of a second.			Time in hundredths of a second.		
Line	No.	Time.	Line.	No.	Time.
A	1	9.8	B	1	8
"	2	9.2	"	2	8.5
"	3	9	"	3	7.75
"	4	10.5	"	4	8.8
"	5	9.6	"	5	7.8
"	6	8.1	"	6	8.4
"	7	10	"	7	7.5
A′	1	9.4	"	8	8.75
"	2	10.2	B′	1	6.8
"	3	8.9	"	2	8.2
"	4	9	"	3	8.3
"	5	9.5	"	4	7.8
"	6	10	"	5	7.5
"	7	9.5	"	6	8
"	8	10	"	7	6.7
			"	8	8
Average.		9.5	"	9	8
			"	10	8
			Average.		7.9

Daily rhythm. After six weeks of work it was seen that the daily records indicated a daily rhythm and, when no varying influences were introduced, the records for the corresponding hours of each day were quite similar. The averages of the time required to make 300 taps at the different hours on the days given in Table I, column 1, were as follows :

Time of day.	8 A. M.	10 A. M.	12 M.	2 P. M.	4 P. M.	6 P. M.
Time in seconds.	37.8	35.5	34.6	35.5	33.5	35.1

The following characteristic curve is obtained from these averages. This curve would be much less significant did it not correspond very closely in shape to the normal daily curve.



NOTE.—Distance along the abscissae represents time of day; along the ordinates the number of seconds required to make 300 taps.

The shape of this curve was unexpected, for it was naturally thought that the greatest rapidity would be attained sometime during the forenoon. It will be shown later that the rate at which it was possible to tap was increased by mental excitement or activity, This fact is in harmony with the daily rhythm. The activity of the central nervous system probably increased during the hours of work from 8 to 12, lessened during the noon hour of relaxation, increased again until 4 o'clock in the afternoon, and then, the chief work of the day being over, again decreased. The close correspondence of this curve to the daily programme of work for two years previous is suggestive in the direction of habit; these were spent in public school work with a daily programme beginning at 8 a. m. and closing at 4 p. m., with an hour and a half intermission at noon.

It is probable also, that corresponding changes in the tonus of the muscles of the body, accompanied the changes of central activity, and this increased muscular tension mechani-

cally favored the rapidity of the movements. The decreased rate at 2 p. m. cannot be accounted for by the walk to and from meals, as special experiments showed that the rate was not affected by such short walks. The rise at 6 p. m. may partly be due to fatigue, but it is thought to be chiefly due to an unconscious relaxation, as the chief work of the day ended at 4 p. m. By a careful study of the barometric charts extending over the whole series of experiments, it was found that no effect of atmospheric pressure could be detected.

Effect of Muscular Exercise. After almost two months of work it was noticed that irregularities were introduced into the daily curve when a vigorous walk had been taken. To test this, walks were purposely taken between different periods of work for a series of days; the following table shows the average results; these averages would be less significant, did not the individual cases show every time a decreased rate after the walk:

Before Walking.		After Walking.		
Time of Day.	Time in sec. for 300 taps.	Time of Day.	Time in sec. for 300 taps.	Difference.
8 a. m.	41.75	10 a. m.	43.75	2 sec.
10 a. m.	39	12 m.	43.5	4.5 "
12 m.	36.5	2 p. m.	44.5	8.5 "
2 p. m.	39	4 p. m.	44	5 "
4 p. m.	39	6 p. m.	46	7 "

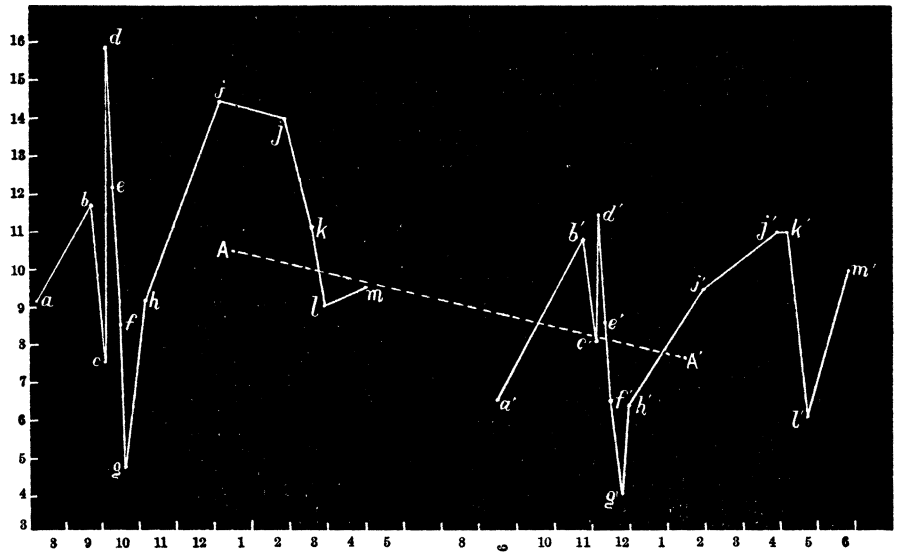
This falling off in rate after a walk is probably due to (a) general fatigue and (b) mental relaxation induced by the walk, because a walk toward the close of the day when the normal rate was the highest, produced more marked effect than a similar walk in the morning.

Effect of Vigorous Mental Exercise. It was noticed by a comparison of records and the daily journal, that strong mental concentration, especially if accompanied with the excitement of interest, was favorable to rapidity of movement. To test this further, records were taken immediately before and after sorting into heaps as rapidly as possible 80 cards of 10 different kinds. Several packs were rapidly distributed with a few seconds rest between, until it required the utmost concentration to fix and keep the position of the different kinds

in mind. The exercise is somewhat exciting and to make the best time it requires the most undivided attention. The following table gives the time in seconds required for making 300 taps before and after such experiments:

Before Sorting Cards.			After Sorting Cards.		
Date.	Time of Day.	Time in sec. for 300 taps.	Time of Day.	Time in sec. for 300 taps.	
Apr. 5	3.00 p. m.	44	4.00 p. m.	41	—3
" 8	10.45 a. m.	34.75	11.05 a. m.	38	+3¼
" 8	5.05 p. m.	39.5	5.45 p. m.	39	—½
" 9	8.10 a. m.	39	8.30 a. m.	36.5	—2½
" 9	11.10 a. m.	39.25	12.00 m.	36.5	—2¾
" 11	10.10 a. m.	46	10.45 a. m.	40.75	—5¼
" 11	3.40 p. m.	41	4.05 p. m.	41	0
" 12	4.00 p. m.	39	4.45 p. m.	36	—3
" 13	10.35 a. m.	38.5	11.20 a. m.	38.5	0
" 14	1.15 p. m.	44.5	2.00 p. m.	39.5	—5
" 15	9.45 a. m.	41.75	11.05 a. m.	41.5	—¼
" 16	10.05 a. m.	37.5	11.45 a. m.	34	—3½
" 18	10.25 a. m.	42.25	11.30 a. m.	36.5	—5¾

The similarity of the curves for these figures is very striking, and they also show the marked difference in rate.



Before Sorting Cards. After Sorting Cards.

NOTE.—Points a, b, c, d, etc., curve I, represent tests before sorting cards, and a', b', c', d', etc., curve II, corresponding tests after sorting cards. The dotted line, $A\,A'$, connects the points representing the averages before and after sorting the cards.

After studying the variations caused by such severe mental work, and taking into the account that vigorous physical exercise had produced the opposite effect, it seemed probable that the increase in rate was due to increased central activity and the unconscious tension of the muscles attending this central excitation. This view was somewhat strengthened, when a study of the whole series of experiments revealed the fact that an increased rate had accompanied mental excitement. For example, the rate was increased after reading an interesting unexpected letter, after the announcement of a distinguished visitor to inspect the work, and just before reading a paper before the psychological seminary. While these observations are too few to base upon them definite statements, they are of value, because such conditions cannot be manufactured at will.

From the results of these observations the suggestion came that such influences might throw light on the difference be-

tween sensory and motor reaction-time. The following table shows a series of reactions before and after sorting cards as previously explained, given in thousandths of a second and obtained with a Hipp chronoscope:

Sensory.		Motor.	
Before Cards.	After Cards.	Before Cards.	After Cards.
128	161	117	124
131	123	103	131
215	134	116	121
131	146	111	116
130	151	116	117
197	151	119	115
165	148	123	117
147	114	104	107
181	129	118	110
141	140	115	109
126	161	126	103
157	143	142	105
129	107	158	118
116	123	122	108
133	137	130	109
136	115	140	115
154	131	136	121
138	110	232	104
134	117	149	114
214	126	108	129
139	164	117	107
121	191	115	111
151	132	130	146
130	136	131	98
171	140	156	119
160	129	121	116
155	200	123	126
140	166	107	113
215	135	126	113
180	121		
		Aver. 128.3	Aver. 118.6
Aver. 152.1	Aver. 139.3		
Av. var. 19.1	Av. var. 16.6	Av. var. 15.5	Av. var. 8.06

These differences in reaction-times—which are relative and not absolute—must depend chiefly and primarily on changed central conditions; for even if, as has been suggested, the muscles are in a greater state of tension after such mental exercises, it is a result of an unconscious partial innervation of the muscles of the body accompanying increased central activity. If it be true that general muscular tension is produced by mental concentration, it leads to the very important suggestion, viz.: that the chief cause of the feeling of bodily

weariness resulting from mental concentration, may be due to muscular fatigue.

Experiments on Others. Experiments were made at my request by two other men. They followed the same programme that I had used. Records were taken for seventeen days by B., and for six days by L. In neither case was there developed any marked daily rhythm. B.'s averages for the different hours, show the greatest rapidity at 8 a. m. and the least at 6 p. m., while the rate at the other four hours was approximately the same. The mean variation is so large, however, that these averages are comparatively meaningless. The daily rhythm in my own case did not make its characteristic appearance until after almost a month's practice. The only definite results from the work of B. and L. are their rates and the effect of exercise which will be spoken of further on. B.'s rate for the whole series of tests made was 6.4 taps per second; for L. the rate was 6.8 taps per second.

During the course of the experiments tests were made upon a number of visitors. The accompanying table shows their rates, and is of interest in that great individual differences are shown.

RATE OF VISITORS.

Date.	Individual.	Time of Day.	Time in sec. for 300 taps.		Date.	Individual.	Time of Day.	Time in sec. for 300 taps.	
			Right Hand.	Left Hand.				Right Hand.	Left Hand.
1892					1892				
Feb. 5	A.	11.10 a. m.	45	68	Mar. 8	L.	2.30 p. m.	47	
" "	B.	11.30 a. m.	46	49	" 12	M.	5.30 p. m.	57	
" "	C.	11.00 a. m.	42.5	51.5	" 12	N.	5.30 p. m.	47.25	
" "	D.	6.00 p. m.	46	50	Apr. 4	O.	10.00 a. m.	53	
" "	E.	9.00 a. m.	44	57	" 10	P.	12.00 m.	50	
" 9	F.	10.30 a. m.	45	60	" 10	Q.	1.00 p. m.	67	
" 9	G.	4.00 p. m.	46	54	" 10	R.	1.00 p. m.	51.5	62
" 9	H.	4.10 p. m.	49		" 15	S.	2.00 p. m.	66	
" 9	I.	4.15 p. m.	51.5		" 15	T.	2.00 p. m.	57	
" 22	J.	4.30 p. m.	52						
Mar. 4	K.	4.00 p. m.	48						

Effect of Practice. The average rates of B. and L. were reached on the third day, and no perceptible increase came in the remainder of two weeks' work. The increased normal rate seemed to be chiefly due to the fact that fatigue ceased, which was shown in the greater regularity of the curves. All visitors who took a record for the first time complained of fatigue, and the change in the direction of their curve toward the close of a record plainly showed their diminishing rate. In my own case the average ability had been attained while testing and perfecting the apparatus previous to recording any work. In order to test the effect of exercise of the right hand upon the left, the rate of the left was found at the beginning of the experiment, and again, after more than two months of work. The result shows no gain in the left. If the rate of the left had been influenced any it occurred before any records were taken.

Effect of Rest. The effect of a day of rest, when the subject was in good health, was very slight as shown by comparing the records of two Saturdays and two following Mondays:

Saturdays.							Mondays.						
Time of Day.	8 A.M.	10 A.M.	12 M.	2 P.M.	4 P.M.	6 P.M.	Time of Day.	8 A.M.	10 A.M.	12 M.	2 P.M.	4 P.M.	6 P.M.
Time in sec. for 300 taps.	43	41	36	40	36	40	Time in sec. for 300 taps.	42	43	38.5	43	40	43.25
	39	37.5	36.5	40	36	38		40.5	40	39	40	36	42

From the above table it is seen that the control was slightly weakened for Mondays rather than strengthened; a marked difference is shown between two Saturdays and the following Mondays, during a period of overwork, resulting in a week's illness:

Saturdays.							Mondays.						
Time of Day.	8 A.M.	10 A.M.	12 M.	2 P.M.	4 P.M.	6 P.M.	Time of Day.	8 A.M.	10 A.M.	12 M.	2 P.M.	4 P.M.	6 P.M.
Time in sec. for 300 taps.	37	38.5	37.5	39.5	34.5	37	Time in sec. for 300 taps.	38.75	32.5	32.6	30	30.5	32
	37	35	35	36.5	34.5	Ill		40.5	36	38.5	33	Ill	Ill

These observations are recorded merely from their suggestiveness.

Although we have subjective evidence of varying degrees of mental activity we have very few methods of accurately estimating its condition. The fact that central activity is accompanied with the power to make rapid voluntary movements suggests that the rate at which voluntary movements can be made, may be taken as something of an index to central nervous activity. The following facts may be stated as the chief results of this research:

1. The apparatus described furnishes a convenient and accurate method of recording and counting rapid voluntary movements.

2. The normal rate for the most rapid voluntary movements of the right wrist was found to average 8.5 taps per second.

3. During the work a daily rhythm was developed with the slowest rate at 8 a. m., and the most rapid at 4 p. m.

4. A vigorous walk decreases the rate for rapid voluntary movements of the wrist.

5. Increased central activity favors increased rapidity for voluntary movements.